GEM Challenge 2008: ground magnetic field perturbations

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Background and motivation

- Need for a systematic and independent evaluation of the prediction performance of the state-of-the-art models.
- GGCM Metrics and Validation Focus Group tasked to arrange GEM Challenge on the inner magnetospheric dynamics and ground magnetic field perturbations.
- Ideally, repeat the exercise, for example, every 2-4 years to quantify and guide the progress in the field.

Data preparation

- Selected storm events:
  1. October 29, 2003 06:00 UT - October 30, 06:00 UT.
  2. December 14, 2006 12:00 UT - December 16, 00:00 UT.
  3. August 31, 2001 00:00 UT - September 1, 00:00 UT.
  4. August 31, 2005 10:00 UT - September 1, 12:00 UT.
- For this particular analysis, 12 ground magnetometer stations were selected based on the spatiotemporal coverage.

Data preparation

- One-minute geomagnetic field data downloaded via INTERMAGNET.
- Visually detected baseline removed to obtain the disturbance field.
- Small data gaps no longer than few minutes patched via linear interpolation.

Methods of analysis

- Polar plots of the horizontal magnetic field vectors generated for preliminary visual inspection.
- Mean (over 2 hour windows and different stations) power spectra generated for both observed and modeled field fluctuations.

Methods of analysis

- "Metrics" analysis
  - The term *metric* not used in a strict mathematical sense but to refer to more general functions mapping two elements of a set into a single real number.
  - The computed number quantifies the model performance in terms of "distance" from the perfect performance.
  - Different metrics measure different aspects of the model performance.
  - Two metrics selected for the initial analysis.

Methods of analysis

- Prediction efficiency:

$$PE(x_{obs}, x_{mod}) = 1 - \frac{\left\langle (x_{obs} - x_{mod})^2 \right\rangle_t}{\sigma_{obs}^2}$$

Perfect model, *PE=1*

- Log-spectral distance (GIC-related derivation)

$$M_s(\tilde{\mathbf{x}}_{obs}, \tilde{\mathbf{x}}_{mod}) = \sqrt{\sum_{\omega} \left(\log \frac{|\tilde{x}_1|_{obs} + |\tilde{x}_2|_{obs}}{|\tilde{x}_1|_{mod} + |\tilde{x}_2|_{mod}} \right)^2}$$

Perfect model, $M_s=0$

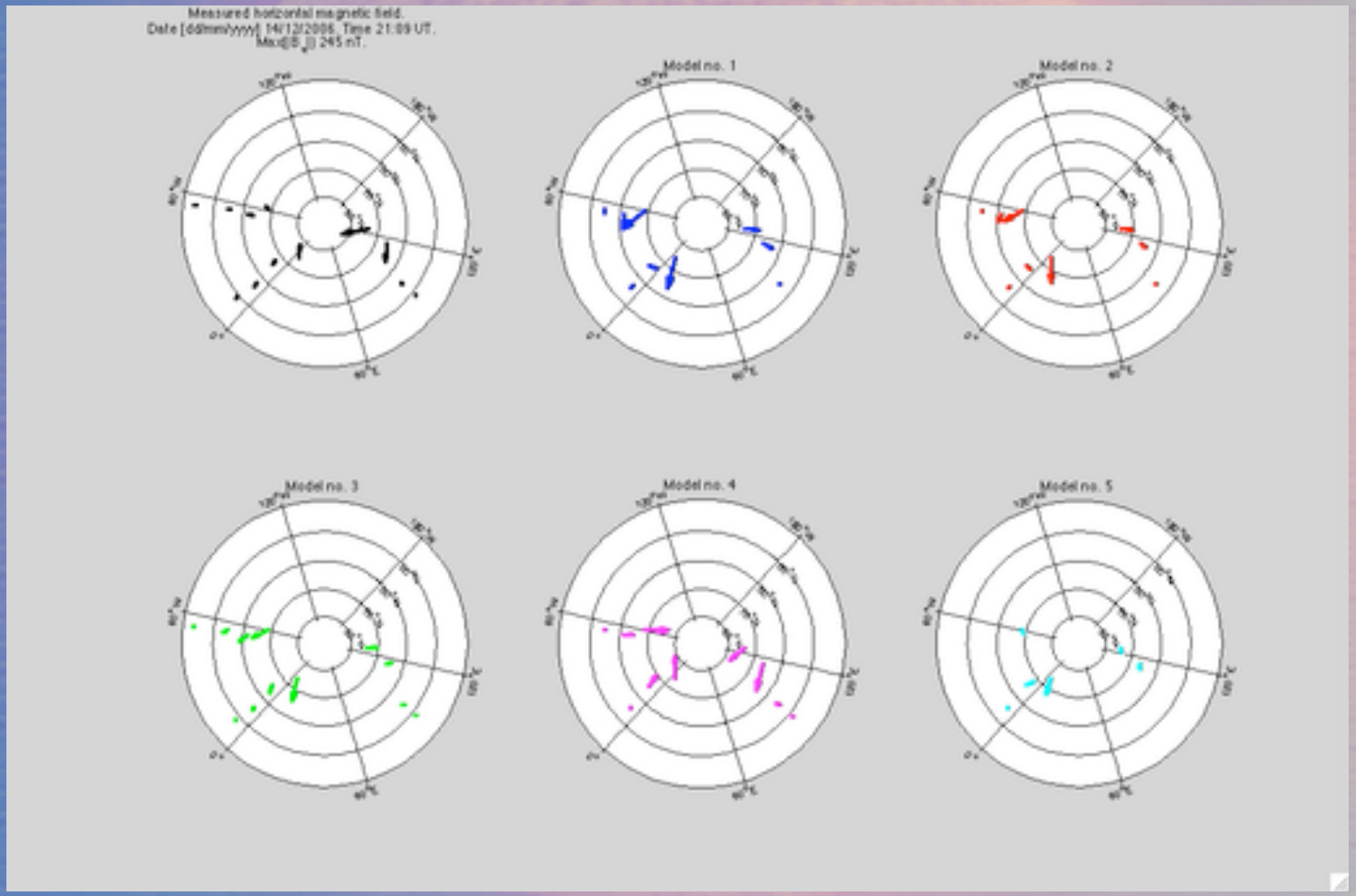
Ground magnetic field perturbations computed from MHD by using the methods introduced in *Pulkkinen et al.* (2007).

Initial results

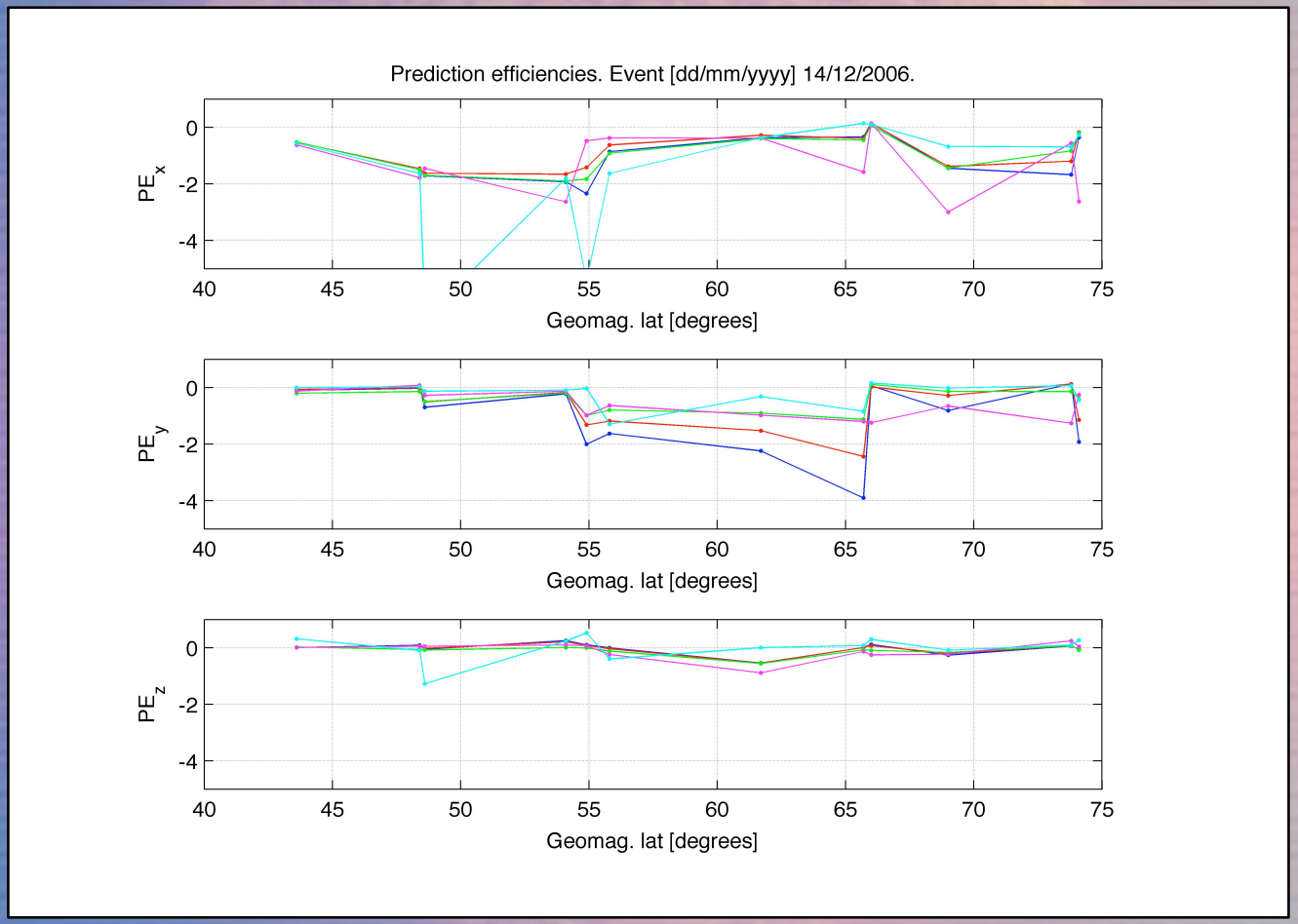
Table 3. Global MHD models and the model setups used in the study. The third column indicates the color codes used in the figures. In the text different model setups are referred as different "models".

Model #	Model description	Color code
1	BATS-R-US v7.73, number of cells: 700000	blue
2	BATS-R-US v7.73, number of cells: 2 million	red
3	BATS-R-US v8.01 coupled to RCM, number of cells: 2 million	green
4	OpenGGCM v3.1, number of cells: 3 million	magenta
5	Weimer (2005, JGR), 4-min. output interpolated to 1 min.	cyan

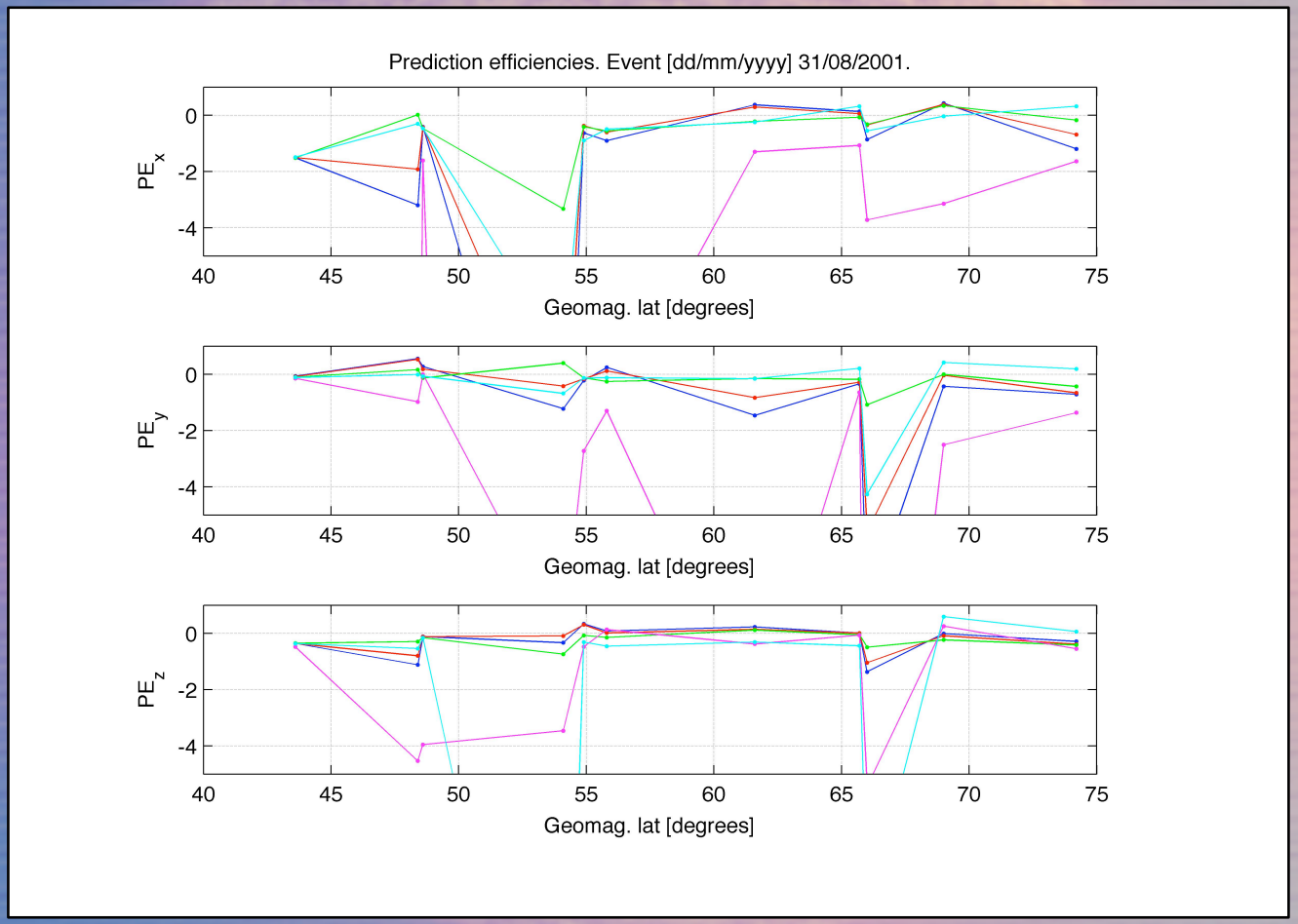
Initial results: polar plot (December 14, 2006)



Initial results: prediction efficiency



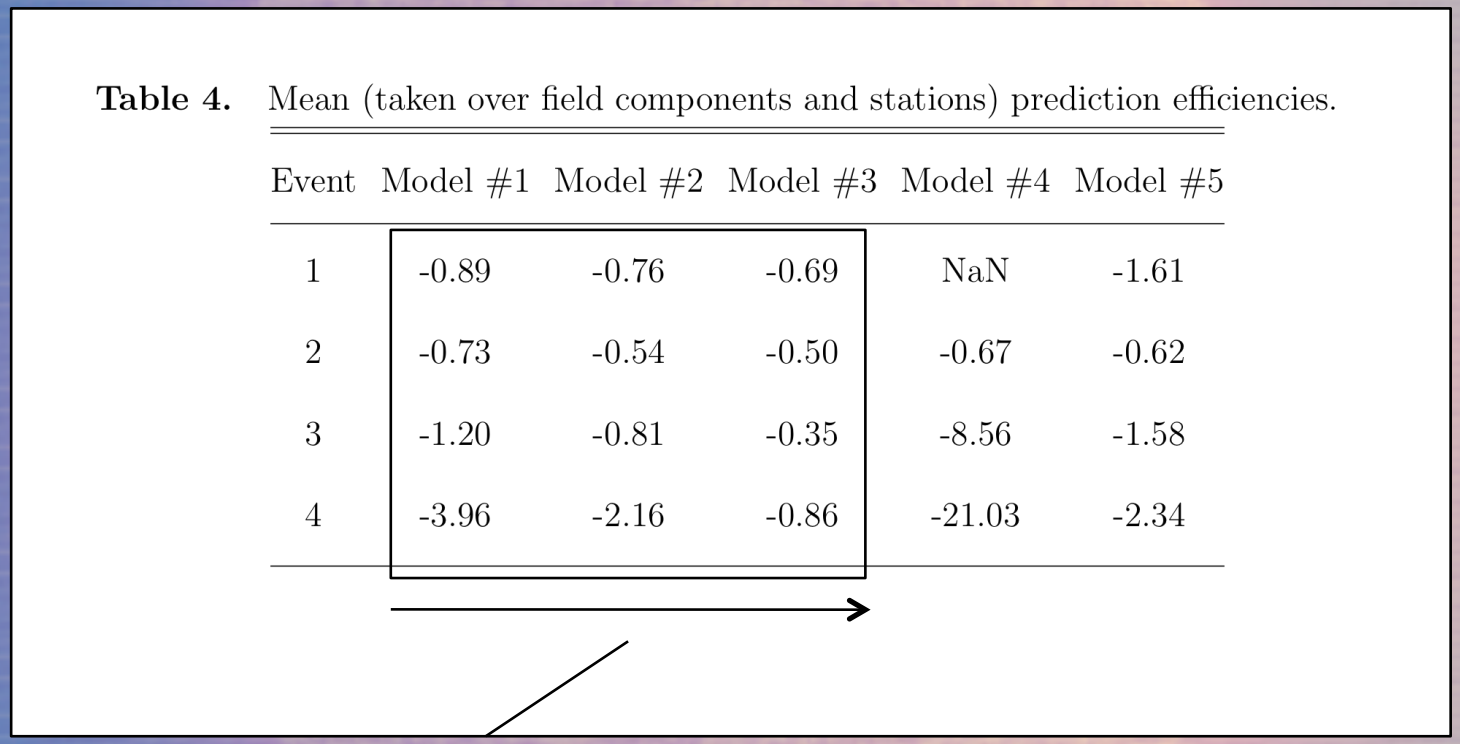
Initial results: prediction efficiency



Initial results: prediction efficiency

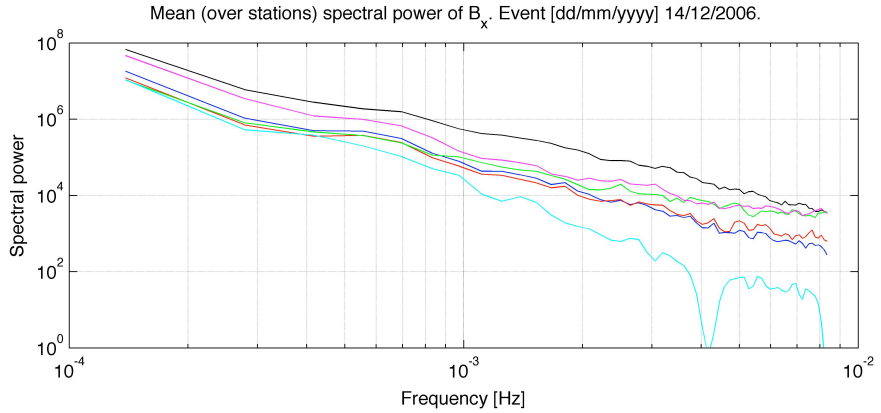
Table 4. Mean (taken over field components and stations) prediction efficiencies.

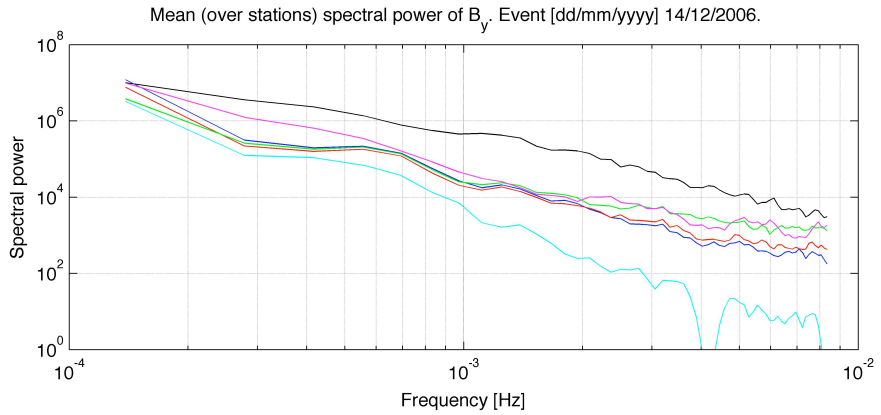
Event	Model #1	Model #2	Model #3	Model #4	Model #5
1	-0.89	-0.76	-0.69	NaN	-1.61
2	-0.73	-0.54	-0.50	-0.67	-0.62
3	-1.20	-0.81	-0.35	-8.56	-1.58
4	-3.96	-2.16	-0.86	-21.03	-2.34



Systematic improvement

Initial results: power spectrum





Periods 2-120 min.

Initial results: power spectrum

Table 5. Metric M_s computed from mean power spectra in Fig. 3.

Event	Model #1	Model #2	Model #3	Model #4	Model #5
1	51	53	22	NaN	186
2	77	71	45	39	171
3	53	43	34	9	134
4	46	52	36	10	131

Quite systematic improvement

Summary

- Observed and modeled data for 12 magnetometer stations analyzed for four storm events.
- Identical analyses will be carried out for all GEM Challenge 2008 ground magnetic field submissions.